The Effect of Motor and Cognitive Tasks on Gait in People with Stroke

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Objective: Gait of people with unilateral stroke is characterized by pronounced asymmetry. The aim of the study was to investigate the effect of cognitive and motor tasks on asymmetry of gait in people with stroke. *Materials and Methods*: Nine individuals with stroke walked over the GAITRite walkway while performing motor (holding a cup with water) or cognitive (reciting the alphabet) tasks or walked with no additional task. Gait velocity, cadence, and symmetry indexes for the stance phase, swing phase, and single support phase of a gait cycle were calculated. *Results*: The motor and cognitive tasks negatively affected gait velocity ($P < .05$) and cadence ($P < .05$). Walking and performing additional tasks resulted in the increase of the asymmetry of gait. The cognitive task had a greater effect on gait asymmetry than the motor task. *Conclusions:* The study outcome revealed that gait of individuals with stroke could be affected by simultaneous performance of additional tasks. The outcome provides a basis for future investigation of the ways of improving symmetry of gait in people with stroke.

Key Words: Stroke—gait—additional task—asymmetry

Introduction

Stroke is a leading cause of long-term disability in the United States with a large number of those who experienced a stroke suffering from hemiparesis.[1] Individuals with hemiparesis due to stroke show increased reliance on the unaffected lower extremity in standing[2] as well as during ambulation[3] which leads to impairment of balance and gait.[4]

Individuals with stroke walk slower than healthy counterparts.[5] Moreover, gait of people with unilateral stroke is characterized by pronounced asymmetry seen as shorter single-limb stance time, prolonged swing time, and decreased ground reaction forces on the affected limb relative to the unaffected limb.[3,5-8] Stroke-related gait asymmetry was linked to the muscle weakness, impaired muscle activation,[9,10] asymmetry of weight bearing,[11,12] and decreased dynamic balance.[13] Gait asymmetry in individuals with stroke leads to a decreased efficiency of ambulation, reduced performance of the activities of daily living, and increased risk of falls.[14]

Previous studies showed that individuals with stroke performing cognitive tasks walk with decreased walking speed.[15,16] It was also demonstrated that different cognitive and motor tasks could have different impacts on poststroke gait mostly affecting cadence, gait speed, and stride length.[16,17-19] Moreover, it was reported recently that treadmill cognitive dual-task training improves gait velocity, cadence, and single support time in individuals with chronic stroke.[20] However, the majority of studies investigating the effect of training on gait of individuals with stroke do not focus on the improvement in gait symmetry most likely because there is not enough information on how performance of different tasks affects the asymmetry of gait in individuals with stroke. Thus, the purpose of the study was to investigate the effect of cognitive and motor tasks on gait in individuals with stroke. We hypothesized that performance of cognitive and motor tasks would adversely affect gait velocity and gait asymmetry. Moreover, we hypothesized that walking simultaneously performing a cognitive task would increase gait asymmetry more than walking and performing a motor task.

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Method

Participants

Nine individuals with stroke who satisfied the inclusion/exclusion criteria (described below) were selected to participate in the study. The subjects were 6 men and 3 women (mean age 54.4 ± 4.8 years and 6.6 ± 2.4 years poststroke accident). Six participants had a right-side hemiparesis and 3 had a left side hemiparesis. All participants were independently walkers. Inclusion criteria were as follows: more than 1-year poststroke accident, identified by a clinician asymmetry of stance and gait, ability to walk without assistance, and ability to follow the instructions. Exclusion criteria were as follows: cardiovascular, pulmonary, or neurological complications, a Berg Balance Scale score of less than 41, and a Mini-Mental State Exam score of less than 24. The demographic and clinical information is reported in Table 1. The study was conducted with the formal approval of the local human subject Institutional Review Board and each participant signed a written informed consent.

Instrumentation and Procedure

Each participant's gait was evaluated using the GAITRite walkway (CIR Systems, Inc., Havertown, PA). High reliability and validity have been reported for the GAITRite system compared to other instruments.[21] The GAITRite walkway was positioned in the hallway such that a subject started walking 2 meters prior to stepping on the walkway and continued walking 2 meters past the end of the walkway. Three experimental conditions were implemented. First, the subjects were instructed to walk with a self-selected comfortable speed without performance of an additional task (normal gait, NG). Second, during walking, the subjects were required to use their unaffected arm to carry a cup with no handle filled with water up to 1 cm from the top edge of the cup and not spill it (walking with performance of a manual task [GwMT]). Third, the participants were instructed to walk while reciting the alphabet aloud by skipping 2 letters. For example, if the participants were told to start with 'A' letter, they were required to say 'A, D, G, and so on' (walking with performance of a cognitive task [GwCT]). Three trials were recorded in each condition and the order of conditions was randomized. The mean value of the 3 trials was used in the data analysis.

Table 1. *Demographics and baseline characteristics of the study participants*

Characteristics	Mean ± SD
Age (y)	54.44 ± 4.87
Gender (F/M)	3/6
Weight (kg)	78.74 ± 20.68
Height (cm)	167.27 ± 8.77
Time since stroke (y)	6.66 ± 2.44
Type of stroke (ischemic/hemorrhagic)	5/4
Affected side (right/left)	6/3
Fugl Meyer upper extremity/ motor score (FMUE)	33.89 ± 16.68
Fugl Meyer lower extremity/ motor score (FMLE)	25.56 ± 5.08
Modified Ashworth Scale (MAS)	2.67 ± .58
Weight bearing on the affected side (%)	31.25 ± 9.80
Mini-Mental State Exam score (MMSE)	28.78 ± 1.78
Berg Balance Scale score (BBS)	51.78 ± 1.99
Activities-specific Balance Confidence (ABC) Scale	73.43 ± 19.06
Hand dominance (Right/Left)	8/1

Data Analysis

Gait velocity (cm/seconds), cadence (the rate at which a person walk, expressed in steps per minute), duration of stance phase (%), swing phase (%), and single support phase of a gait cycle were calculated by the GAITRite software. The symmetry indexes (SI) for the stance phase, swing phase, and single support phase of a gait cycle during gait were calculated using the following Equation.

$$\mathrm{SI} = \frac{V_{unaffected} - V_{affected}}{\frac{1}{2}\left(V_{unafected} + V_{affected}\right)} \times 100$$

where $V_{affected}$ is the corresponding variable obtained from the affected side; $V_{unafected}$ is the corresponding variable obtained from the unaffected side. When SI equals 0, the left and right sides are in perfect symmetry.[3]

Statistical Analysis

Wilcoxon Signed Rank test was used to evaluate changes in velocity, cadence, and SI for the stance phase, swing phase, and single support phase of a gait cycle between experimental conditions (NG, GwMT, and GwCT). Statistical significance was set at $P < .05$.

RESULTS

Gait Velocity and Cadence

Mean walking velocity during the 3 experimental conditions ranged from 63.99 to 75.63 cm/seconds and there was a significant reduction in gait velocity during performance of both the cognitive and motor tasks (Fig 1). Thus, velocity of gait was 75.63 ± 15.79 cm/seconds while walking without performance of manual or cognitive tasks. Gait velocity reduced during the performance of the manual task to 64.55 ± 14.90 cm/seconds and during the performance of the cognitive task to 63.99 ± 16.02 cm/seconds. Gait velocity measured during performance of a motor task (GwMT) or performance of a cognitive task (GwCT) was statistically different from velocity of gait while walking with no additional task (NG) ($P < .05$). The difference in velocity between walking with a manual

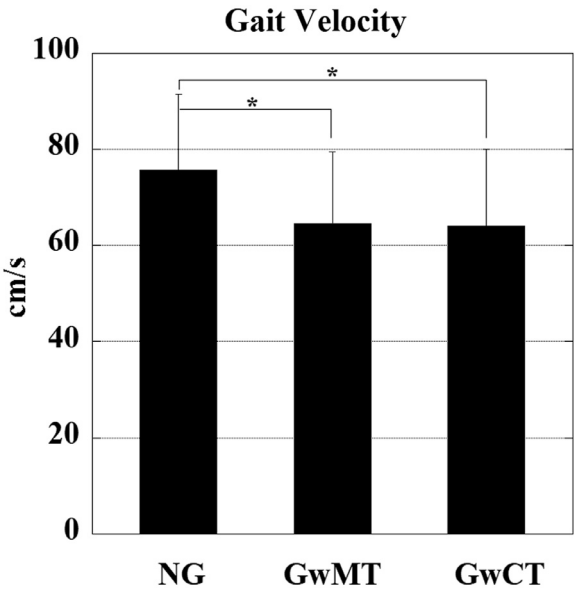

Figure 1. *Gait velocity measured while walking with no additional task (NG) and when walking and performing a motor task (GwMT) or cognitive task (GwCT). Mean and SE are shown. Asterisks (*) indicate significant difference between the conditions* (P < .05).

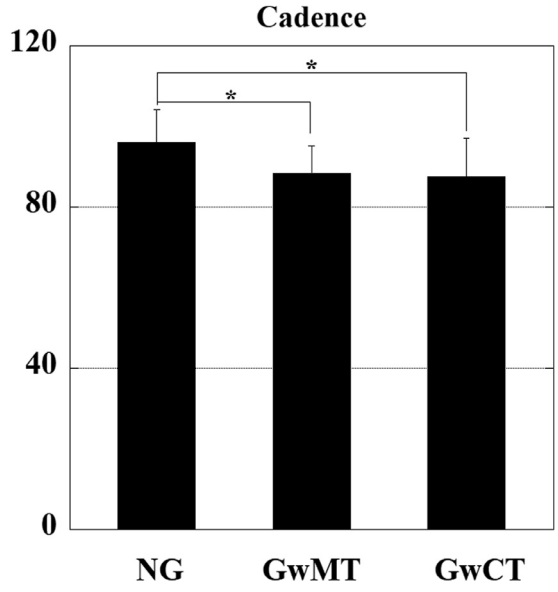

Figure 2. *Cadence measured while walking with no additional task (NG) and when walking and performing a motor task (GwMT) or cognitive task (GwCT). Mean and SE are shown. Asterisks (*) indicate significant difference between the conditions* (P < .05).

task (GwMT) and a cognitive task (GwCT) was not significant.

Cadence while walking with no additional task (NG) was 96.06 ± 8.15; it was 88.35 ± 6.86 and 87.47 ± 9.52 while walking with a cup and reciting the letters of the alphabet, respectively. The difference between walking and performing a motor task (GwMT) and walking with no additional task (NG) and between walking and performing a cognitive task (GwCT) and NG was statistically significant ($P < .05$) (Fig 2). The difference in cadence between walking with a manual task (GwMT) and a cognitive task (GwCT) was not significant.

Symmetry Indexes

There were differences in symmetry of gait during walking (Table 2).

Thus, SI for the single support time while walking and performing a motor task (GwMT) was larger as compared to walking without additional tasks indicating that the asymmetry of gait was increased. When study participants walked performing a cognitive task (GwCT), their SI increased indicating that gait asymmetry increased further. The difference, however, was not significant. SI calculated for the stance and swing phases of gait also increased when the participants were required to walk performing motor or cognitive tasks as compared to normal gait (NG) (Table 2). The SI indexes between conditions however, were not significantly different.

Discussion

Performing an additional task while walking resulted in decrease of gait velocity and cadence in individuals with stroke. Thus, the first hypothesis that performance of cognitive and motor tasks would adversely affect gait of individuals with stroke was supported. Moreover, when individuals with stroke performed a cognitive task, their gait asymmetry increased more as compared to walking and executing a motor task. Hence, the second hypothesis that walking simultaneously performing a cognitive task would increase gait asymmetry in individuals with stroke more that walking and performing a motor task was supported.

Role of an Additional Task on Gait Velocity and Cadence

Muscle weakness, inadequate muscle coactivation, sensory and visual deficits, noncontractile soft-tissue tightness, and disruption in central generation of programmed

Table 2. *Symmetry indexes (SI) for the single support, stance, and swing phases while walking with no cognitive or motor task (NG) and when walking and performing a motor task (GwMT) and cognitive task (GwCT)*

Variable	Condition	Symmetry index (SI)
Single support phase SI	NG	49.94 ± 22.41
	GwMT	51.74 ± 24.22
	GwCT	55.38 ± 29.78
Stance phase SI	NG	26.44 ± 15.16
	GwMT	25.22 ± 15.21
	GwCT	28.57 ± 17.96
Swing phase SI	NG	45.63 ± 16.32
	GwMT	47.76 ± 18.15
	GwCT	53.36 ± 29.33

muscle activation are described as the impairment factors playing an important role in decreased gait velocity in individuals with stroke.[9,10] Moreover, a need to divide attention between walking and simultaneously performing a secondary task negatively affects gait velocity. Thus, walking and concurrently performing a cognitive task reduced gait speed in individuals with stroke.[19,22,23]

The individuals with stroke participating in the study walked with gait velocity of 75.63 ± 15.79 cm/seconds. Walking with gait velocity of 40-80 cm/seconds categorize them as limited community ambulators.[24] When the participants were required to walk and perform a cognitive or motor task their gait velocity decreased. Thus, individuals with stroke walked 11.08 cm/seconds and 11.64 cm/seconds slower when performing a manual or cognitive task respectively as compared to walking with no additional task. Although walking with gait velocity of 64.55 ± 14.90 and 63.99 ± 16.02 cm/seconds while performing additional tasks is still above the velocity 49 cm/seconds that discriminate between home and community ambulators,[24] it represents a sufficient decline in gait velocity. Given that that 13 cm/seconds improvement in gait velocity is considered as an important achievement for patients undergoing inpatient rehabilitation after stroke,[25] the observed additional task-related decline in velocity of gait could eliminate the gain and as such should be taken into consideration when planning rehabilitation interventions.

During performance of additional tasks, cadence of the study participants decreased. This result as well as the observed decrease in gait velocity are in line with the literature describing the existence of a significant correlation between cadence and gait velocity so cadence decreased as gait velocity decreased.[26] Moreover, it was reported that people with stroke have decreased walking cadence as compared to healthy age-matched controls[5] and walking with decreased cadence could be considered as a compensation for impaired motor control.[27] When individuals with stroke walked performing an additional task, their cadence decreased reflecting compensation associated with a need to perform either motor or cognitive task.

The Effect of an Additional Task on Gait Asymmetry

It is reported that gait asymmetry, commonly present in individuals with stroke,[28-30] could affect the efficiency of locomotion[13,31] and is associated with the increased probability of falls.[14] The outcome of the current study demonstrated that individuals with stroke participated in the study exhibited gait asymmetry which is in line with the findings described in prior studies.

The asymmetry of gait of individuals with stroke was enlarged when they were required to walk and perform manual or cognitive tasks. Thus, asymmetry of the single support phase as compared to walking with no additional task increased 3.6% and 10.9% when walking with the manual task and cognitive task, respectively. Asymmetry of stance phase increased 4.7% and 8.1% as compared to walking with no additional task. Finally, asymmetry of swing phase of gait increased 4.7% and 16.9% when walking and performing a manual task and walking and reciting letters, respectively compared to walking with no additional task. Similar increase in the asymmetry of gait was reported in healthy individuals when they were provided with an insole inducing discomfort in the shoe on one side.[32]

The outcome of the study taken together with the outcomes of prior studies suggest that individuals with stroke should pay special attention when they walk and perform additional tasks in order to avoid a fall.[14] The probability of a fall could be even greater when 2 additional tasks are performed simultaneously, for example, when walking and talking[19] or walking and texting[33] as texting requires both, holding the phone and performing a cognitive task. Moreover, it is reported that individuals with stroke prioritize the cognitive task, sacrificing walking performance, suggesting that they have the impaired ability to adapt the walking pattern in the presence of a cognitive task.[19,23,34]

There are some study limitations. The sample size of the study participants was relatively small, and their level of impairment was moderate. Another limitation was that we did not quantify the level of difficulty of the cognitive task since only one cognitive task was used. Future studies are needed to investigate the effect of additional tasks on gait of individuals with stroke with wider range of impairments.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2019.104330.

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